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Combined Ultraviolet Studies of Astronomical Sources

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NASA Grant NAG5-87

Semiannual Progress Report No. 12

For the Period 1 February 1986 through 31 July 1986

Principal Investigators

Drs. S. L. Baliunas; A. K. Dupree; M. Elvis;
J. P. Huchra; S. Kenyon; J. C. Raymond;

October 1986

Prepared for
National Aeronautics and Space Administration
Greenbelt, MD 20771

Smithsonian Institution
Astrophysical Observatory
Cambridge, MA 02138

The Smithsonian Astrophysical Observatory
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The NASA Technical Officer for this Grant is Dr. Yoji Kondo
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Cygnus Loop

Three positions were observed; Miller's position 3 in High Dispersion, and two positions along the Hester, Parker and Dufour "spur" at Low Resolution. We confirm the hypothesis that resonant scattering within SNR filaments decreases the intensity of the C IV lines (Raymond *et al.,* Ap. J., **246,** 100). We find that the 'spur' shows less complete cooling and recombination toward its tip as predicted by Hester, Parker and Dufour, but we also find that the shock velocity is higher near the tip, complicating the interpretation of an interstellar cloud struck by the supernova blast wave. Both high and low dispersion optical observations of the IUE positions have been reduced, and we have found the explanation for the 'non-thermal' velocity broadening observed in the Cygnus Loop and the old supernova remnants. We have obtained high dispersion spectra with the Kitt Peak 4.0-m telescope which provide the final observational data for papers on both radiative and non-radiative shocks. One paper is nearly complete. Results were presented at the University of Virginia.

P Cygni Profiles in Dwarf Novae

IUE observations of HL CMa were obtained December 28-30, 1985 with simultaneous optical coverage December 29-30. We now have good coverage through the orbital period and through outburst maximum and decline. C. Mauche has extended the profile model calculations reported at the Sixth Year IUE conference (J. Raymond, p. 301). We find that the wind must be very strongly clumped, perhaps by shocks like those believed to account for O star X-ray emission. The wind must originate in the disk or accelerate very slowly if it originates near the dwarf. Results were presented at the Ninth North American Workshop on Cataclysmic Variables

(Mauche and Raymond 1985, 1986; Raymond and Mauche 1985). We have computed the effect of the Ly α absorption profile on the P Cygni emission of N V. J. Raymond presented an invited review of hot white dwarfs in cataclysmic variables at the AAS Meeting in Houston (Raymond 1986) describing the role of the white dwarf in ionizing the wind.

YY Gem

Observations were carried out February 19-21, 1986. Variations in the C II/C IV intensity ratio with orbital phase were detected. Correlation of line ratios with activity level inferred from Hβ was presented at the International IUE conference (Baliunas *et al.* 1986).

Nova Shells

Observations were carried out February 27 and 28, 1986. The C IV λ1550 line was detected in the shell of DQ Her. We are presently examining the possibility that this is stellar line emission scattered by dust in the nebula.

HZ Herculis

The observations refute the Howarth and Wilson model for the origin of the N V emission line in HZ Her. The X-ray illuminated face of the companion star probably accounts for much of the radiation.

Activity Cycles in Cluster Giants

We have been monitoring the chromospheric and coronal fluxes present in the ultraviolet spectra of the Hyades and Praesepe KO III stars with IUE since 1978. Although ostensibly similar in other physical characteristics, the KO III stars in the

Hyades and Praesepe clusters differ significantly in the ultraviolet for example, by a factor of 6 or more in the high-temperature C IV line flux. One possible explanation for the spread in UV emission strength among these stars is that they are at different phases of long-term activity cycles. We have been monitoring the ultraviolet spectra of these giants since, in order to search for long-term activity variations. Our measurements obtained in mid-March 1986, are being analyzed along with the earlier spectra in the time series.

Alpha Ori

Observations of Alpha Ori (M2 Iab) were acquired as planned twice per month during the times the star was accessible to I.U.E. All of the data taken has been received at the Center for Astrophysics, and reduced. Alpha Ori continues to show irregular fluctuations in brightness superposed upon a slowly varying brightness level consistent with the photometric period of 5.6 years. The measured continuum flux at 3000Å, the Mg II (λ2800) total flux and that of the individual h and k lines are shown in the accompanying figure. In this figure, we note the good agreement between the UV continuum flux and the B magnitude variations. The Mg II lines behave somewhat differently, by lagging the continuum variations by a few tenths of a year. Moreover the ratio of the k line to h line fluxes varies also. The detailed behavior of the Mg II h and k lines components is difficult to interpret, the blue wing of the k line being obscured by a circumstellar Mn I line. The Mg II flux minima (near 1985.0 and 1986.1), following local UV and optical photometric minima near 1984.7 and 1985.9, suggest a periodic short-term variation in the photosphere and chromosphere.

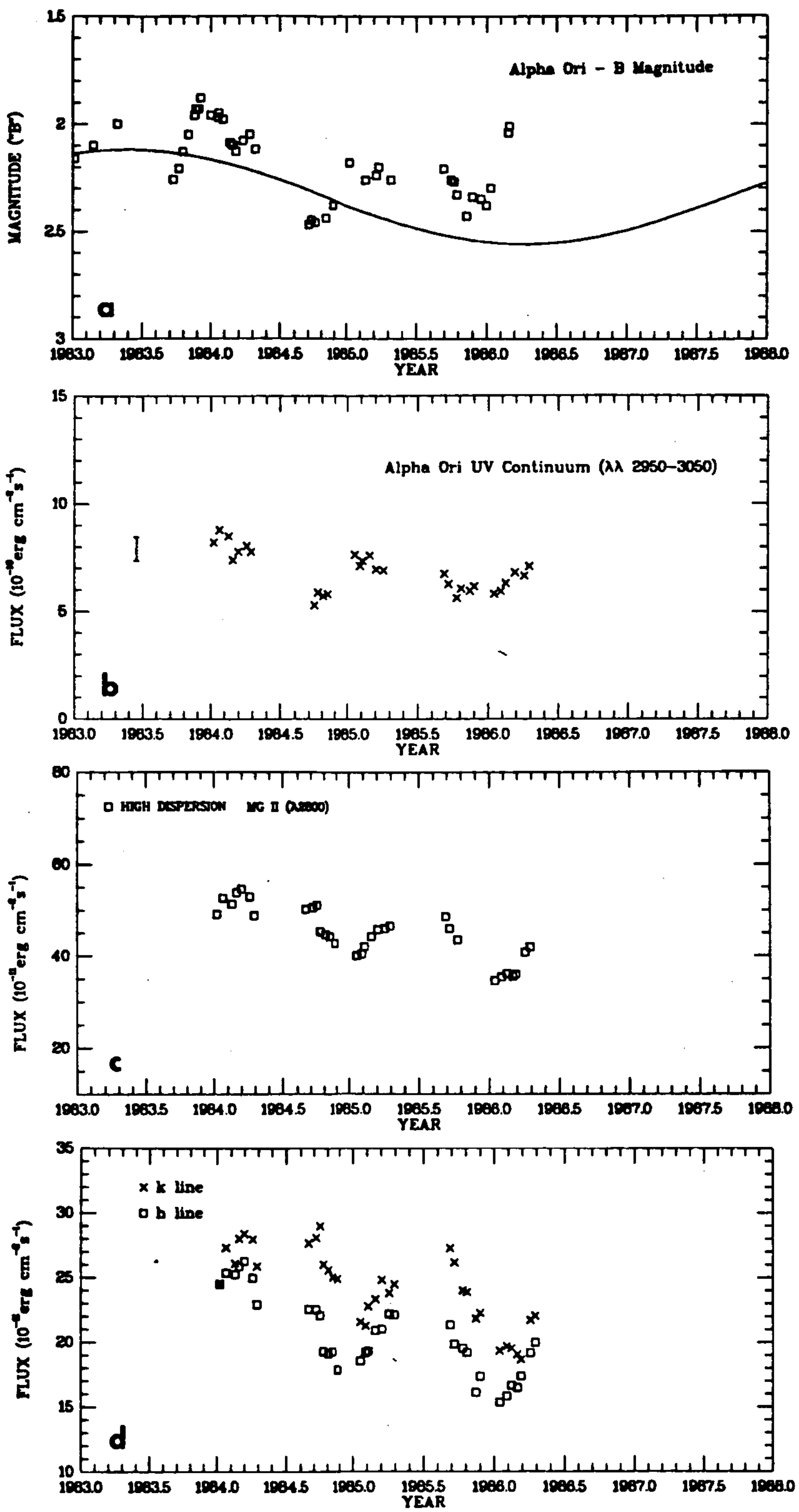

Figure 1. - B magnitude (a), ultraviolet continuum (3000±50 A) flux (b), total Mg II h and k line flux (c), and Mg II h and k line fluxes plotted separately (d) obtained during the 1984-1986 Alpha Ori monitoring program. The ultraviolet continuum flux ±2-sigma error bar is shown in (b). The error in the Mg II fluxes is estimated to be less than four percent.

We are gratified that this program of continuous optical and ultraviolet monitoring of Alpha Ori will be continued for the next two years by recommendation of the IUE Peer Review Panel.

A brief communication describing these results to date was submitted for publication in the Proceedings of the Conference: New Insights in Astrophysics, an ESA/NASA/SERC sponsored conference held in London, England in July 1986.

Metal Deficient Giant Stars

I.U.E. observing time to measure the Mg II profiles at high dispersion in metal deficient giants, has been scheduled for August and October 1986. These exposures will be carried out jointly with ESA by using a shift preceding the NASA shift in order to obtain extended (14 hour) exposures.

UV Spectra of Symbiotic Stars Detected by the VLA

IUE observations have been acquired for CH Cygni (4 LWP and 4 SWP exposures), AG Pegasi (2 LWP and 2 SWP exposures), and RW Hydrae (1 LWP and 1 SWP exposure). Contemporaneous infrared, optical, and radio data have been secured for each *IUE* exposure.

Observations of RW Hya show that it is a fairly simple symbiotic star, consisting of an M giant ($L \sim 1000\ L_\odot$) and a hot, compact companion ($L \sim 200\ L_\odot$; $R \sim 0.1\ R_\odot$). The system is surrounded by an H II region with a radius, $R \sim 10$ AU and an electron density, $n_e \sim 3 \times 10^7\ cm^{-3}$. The radio observations indicate that the giant component loses mass at a rate of $5 \times 10^{-8}\ M_\odot\ yr^{-1}$. The hot star accretes roughly 20% of this material, but requires only $\sim$ 5% of the mass lost by the giant to maintain its present luminosity. Thus, hydrogen must accumulate on

the surface of the hot star, which will eventually lead to a *symbiotic nova* explosion. Results of this study are reported in a paper submitted to the *Astrophysical Journal* (Kenyon and Fernandez-Castro 1987).

CH Cyg has evolved into a high excitation symbiotic star during the course of our program, and has developed into a triple radio source. We found that the radio brightening in this system was accompanied by an evolution of the hot source to higher effective temperature (T $\sim$ 7,000 K to T $\sim$ 150,000 K) at approximately constant luminosity. Thus, the eruption appears to be the result of a nova-like explosion. The eruption is somewhat unusual, in that the maximum luminosity was apparently $\sim$ 100-200 $L_{\odot}$. Such low luminosities are predicted for nova eruptions on very low mass white dwarfs ($\sim$ 0.5 $M_{\odot}$), and we are currently attempting to determine the mass of the hot star from high resolution optical spectroscopy.

Time Variability in Symbiotic Stars

Archival data for CI Cygni has been examined, and analysis of these data is nearly complete. Ultraviolet continuum magnitudes have been measured on over 60 spectra, and a comparison with optical light curves has been finished. Emission line fluxes have been extracted from *IUE* spectra, as well, and have been combined with high quality optical data. We have found that the high ionization lines (He II) are eclipsed when the giant in this binary eclipses its companion (a main sequence star surrounded by a massive accretion disk), while lower ionization lines (Mg II and C IV) are not. It appears that the high ionization lines are formed near the boundary layer of the disk, while the other lines are formed in a wind from the disk itself.

Blue Galaxies

No observations were made during this period. We completed a related paper on the internal dynamics of NGC4214 and NGC 4449, and have drafted a paper on observations of redshifted blue galaxies.

QSOs with IPC X-ray Spectra

Observations were made on April 22, 1986. Data bank spectra has been reduced identically by Richard Green at NOAO and we now have a plan of action for the science analysis to be done with the derived numbers.

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Guinan, E. F., Wacker, S. W., Baliunas, S. L. and Loeser, J. G. "Three-dimensional Mapping of the Atmosphere of an Active K-dwarf", 1985, *Bull. A.A.S.*, **17,** 565.

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